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SUBJECT: **ARCHITECTURAL TECHNICAL GUIDE 0015 (January 1, 2005)**
Thermal Performance Supplement for Existing Construction Financed by the USDA/Rural Housing Service's Section 502 and Section 504 Single Family Housing Programs

The purposes of this Architectural Technical Guide (ATG) are: (1) to briefly explain the thermal performance construction standard applicable to existing residences; (2) to provide supplemental information regarding the application of the thermal performance construction standard; and (3) to explain the calculation of the thermal resistance properties of various materials related to retrofitting existing construction financed by the USDA/Rural Housing Service's Section 502 and Section 504 Single Family Housing Programs. This ATG is organized under the following major headings:

1 Applicable Thermal Performance Construction Standard
2 Methodology for Evaluating the Thermal Performance Properties of Existing Residences
   - Definitions
   - Winter Heating Degree Days chart
   - RD Instruction 1924-A, Exhibit D, Thermal Performance Construction Standards Requirements
   - Calculating "Prescriptive" Thermal Performance Characteristics of Existing Residence Ceiling, Wall, Floor, Foundation Wall, Door, and Window Assemblies

3 Thermal Resistance Properties of Various Building Insulation Materials

Applicable Thermal Performance Construction Standard

The performance standard for evaluating and upgrading the thermal construction of existing "stick-built" and "modular" residences financed by the USDA/Rural Housing Service's Section 502 and Section 504 Single Family Housing Programs is Rural Development Instruction 1924-A, Exhibit D, Subparagraph IV. B. or C. [Ref.: Rural Development Instruction 1924-A, Exhibit D, Subparagraph II.] "Stick-built" refers to non-factory-built construction, designed to conform to a model building code organization's building, plumbing, and mechanical codes and is the most common form of construction. "Modular" refers to factory-built construction designed to conform to a similar standard. "Stick-built" and "modular" construction should be differentiated from "manufactured" residences which are constructed to a different, nation-wide, U.S. Department of Housing and Urban Development building, plumbing, and mechanical standard. Also note that Exhibit D requires the application of a completely different thermal performance construction standard for new “stick-built” and “modular” construction, the *“Model Energy Code”*.

Methodology for Evaluating the Thermal Performance Properties of Existing Residences

The proper application of the requirements contained in Rural Development Instruction 1924-A, Exhibit D, Subparagraph IV. B. or C requires general knowledge of the target thermal resistance properties for existing residences and general knowledge of the methods for calculating the thermal resistance properties of various building components and assemblies in the terms defined in the Instruction. Following is a discussion of the methodology for accomplishing this type of thermal performance analysis, starting with some definitions related to Rural Development Instruction 1924-A, Exhibit D, and concluding with an abridged chart providing information about the thermal resistance properties of various insulation materials since the Exhibit D standard mainly addresses the strongest component of thermal resistance in ceiling, wall, and floor assemblies, building insulation materials.

DEFINITIONS

British thermal unit (Btu). The quantity of heat required to raise the temperature of one pound (.4535 KM.) of water by one degree Fahrenheit (F). For example, one Btu is the amount of heat needed to raise the temperature of one pound of water from 59 degrees F to 60 degrees F.

Glazing. The material set into a sash or door when used as a natural light source and/or for occupant's views of the outdoors.

Heating Degree Days (HDD). Heating degree days are used as a measure of the heating needs of buildings. They are referenced to 65 degrees F (it is thought this would be an appropriate target interior temperature to maintain during the heating season). If the average of a given day's high and low temperature is 65 degrees, then there are no (zero) heating degree days. If the average temperature is 50 degrees F., then there are (65 minus 50 equals) 15 heating degree days. You can add up the degree days for any time period, say the month of January, and get an idea of how much heating is required to heat buildings (to 65 degrees F). The energy industry pays close attention to heating and cooling degree days as a way to predict energy prices.

Colorado climate control demands are biased more toward the heating season than the cooling season for all locations. More severe heating demands are related to higher elevations above sea level, more northerly longitudinal locations, and other climatic influences. They are effectively addressed in Rural Development regulations by location 6001+ heating degree days construction criteria. Typically, a change in elevation of 1,000 feet in Colorado correlates to about a 4-degree Fahrenheit change in temperature (higher equals cooler). RD Instruction 1924-A, Exhibit D, *“Thermal Performance Construction Standards”*, maximum U values for ceiling, wall, and floor assemblies in SFH existing construction are bracketed into 2 heating degree day zones for Colorado, 4501 to 6000 areas and 6001+ areas. The following heating degree days chart highlights the most severe zone **(6001+) reference locations in red**.

WINTER HEATING DEGREE DAYS

(For Locations throughout Colorado)
(The following data has been furnished by the National Weather Service.)

COLORADO LOCATION	HEATING DEGREE DAYS
Akron	6620
Alamosa	8749
Altenbern	7102
Antero Reservoir	11033
Bailey	8944
Blanca	8759
Bonny Dam	6216
Boulder	5554
Briggsdale	6803
Buena Vista	8003
Burlington	6320
Byers	6473
Canon City	4987
Castle Rock	6932
Center	8968
Cheesman	7820
Cherry Creek Dam	6343
Cheyenne Wells	5925
Cimarron	8719
Climax	12684
Cochetopa Creek	10116
Collbran	7363
Colorado National Monument	5799
Colorado Springs	6415
Cortez	6667
Crested Butte	11292
Del Norte	7980
Delta	5927
Denver	6020
Dillon	11218
Dinosaur National Monument	7250
Evergreen	8094
Flagler	6280
Fort Collins	6368
Fort Lewis	8074
Fort Morgan	6460
Fruita	6247

Gateway	5267
Glenwood Springs	7313
Grand Junction	5620
Grand Lake	10605
Grant	9777
Great Sand Dunes NM	7887
Greeley	6306
Green Mountain Dam	9248
Gunnison	10516
Eads	6129
Hayden	8403
Hermit	11375
Holly	5588
Holyoke	6583
John Martin Dam	5603
Julesburg	6447
Kassler	6243
Kit Carson	6372
Kremmling	10095
La Junta	5265
Lake City	9569
Lake George	10022
Lakewood	6158
Lamar	5414
Las Animas	5455
Leroy	6683
Longmont	6443
Manasa	8375
Meredith	9922
Mesa Verde NP	6432
Maybell	8765
Monte Vista	9003
Montrose	6383
New Raymer	6672
Northdale	7401
Norwood	7643
Ordway	6326
Ouray	7639
Palisade	5152
Paonia	6350
Pueblo	5413
Rocky Ford	5289
Rangely	7328
Rico	9585

Rifle	6881
Rush	7222
Ruxton Park	10778
Salida	7355
Saguache	8781
Sedgwick	6221
Silverton	11064
Spicer	10469
Steamboat Springs	9779
Sterling	6541
Stratton	6405
Taylor Park	12006
Telluride	8986
Trinidad	5339
Twin Lakes	10896
Uravan	5726
Vallecito Dam	8248
Walden	10378
Walsenburg	5438
Waterdale	6648
Westcliffe	8318
Wolf Creek Pass	11169
Wray	6160
Yampa	9316
Yellow Jacket	6889
Yuma	5890

Low-emissivity coating. *Low-emissivity* (low-e), window glass coatings were developed in the early 1970s and introduced into the market around 1980. Emissivity is the ability of a surface to emit radiant energy. Part of the energy absorbed by the glass is radiated away from the glass surface. Most low-e coatings reflect 40 to 70 percent of escaping infrared radiation back inward. Low-e coatings also offer a reduction of 5 to 37 percent in ultraviolet radiation entering an interior space and, therefore, offer a dual benefit to homeowners. Low-e coatings on glass can be applied in several ways during manufacturing processes and their assembly within window systems. The presence of the low-e coating is difficult to verify during field inspections. The most reliable method is to check the manufacturer's window sticker for an indication the low-e coating was provided.

(Sample window sticker. Note "Low E" at the upper right)

Max. U = 0.47 window.	Acceptable window glazing:	2-pane with low-emissivity (low-e) coated window
		3-pane window
		2-pane + interior or exterior storm window
Max. U = 0.69 window.	Acceptable window glazing:	2-pane window
		1-pane + interior or exterior storm window

(Note: A maximum U = 0.47 would satisfy Rural Development requirements for new or existing residences; a maximum U = 0.69 window would satisfy Rural Development requirements for only existing residences, per the RD Instruction 1924-A, Exhibit D, IV.B, chart provided below.)

Prescriptive method. A method for achieving thermal performance in construction assemblies by specifying individual component performance rather than averaging heat loss resistance across an entire envelope (which would consider mitigating factors, such as the percentage of window area in walls or over-insulation in an area of a residence). This is as opposed to the "optional" standard also mentioned in RD Instruction 1924-A, Exhibit D. For existing residences, the "prescriptive" standards method is the appropriate method for evaluating and achieving thermal performance.

"R" value. A unit of measure of the ability to resist heat flow. The higher the R value, the higher the insulating capability. The reciprocal of the U value. R = 1/U. Indicated in the Instruction for individual building components (i.e. insulation material only).

"U" value. A coefficient of heat transmission. The lower the U value, the higher the insulating capability. The reciprocal of the R value. U=1/R. Indicated in the Instruction for an overall ceiling, wall, and floor assemblies (i.e. insulation material plus other adjacent materials).

RD INSTRUCTION 1924-A, EXHIBIT D, THERMAL PERFORMANCE CONSTRUCTION STANDARD REQUIREMENTS

"II. POLICY: .....All existing dwellings to be acquired with Rural Development loan funds shall be considered in accordance with paragraph IV B or C of this Exhibit.
(Revised 08-26-94, SPECIAL PN.)"

Prescriptive and optional thermal performance standards are two options available for satisfying Rural Development's goals for existing construction. The "prescriptive" standards are shown in the table below which sets minimum thermal resistance standards for individual building components or for individual assemblies. The "optional" standards are set elsewhere in RD Instruction 1924-A, Exhibit D, which allows the cumulative thermal resistance characteristics of the structure to be averaged against a single numerical performance standard coefficient. In practice, only the prescriptive standards of the following table would be applicable for virtually all everyday situations.

"B. All existing dwellings to be purchased with RH loan and grant funds shall be insulated in accordance with the following:

[SFH Programs]
[Reference RD Instruction 1924-A, Exhibit D, IV.B.]

HDD Zone	Ceiling Max. U Min. R	Walls Max. U Min. R	Floors/rim joists Max. U Min. R	Foundation walls Max. U Min. R	Windows Max. U Min. R	Doors Max. U Min. R
4501 to 6000	.03 32	.05 19 [only where exposed or feasible]	.05 19	.10 10	.69 2	Insulated core door or wood door + storm door
6001+	.026 38	.05 19 [only where exposed or feasible]	.05 19	.10 10	.69 2	Insulated core door or wood door + storm door

(HDD = heating degree days)

(U values are not adjusted for framing. Values calculated for components may be rounded. For example, a wall section with a total R Value of 18.88 converts to a U value of .0529 rounded to .05)"

"Note 2. Walls shall be insulated as near to new construction standards as economically feasible. Any exterior wall framing exposed during repair or rehabilitation work shall have vapor barrier installed and be fully insulated.
(5-12-87) SPECIAL PN"

CALCULATING "PRESCRIPTIVE" THERMAL PERFORMANCE CHARACTERISTICS OF EXISTING RESIDENCE CEILING, WALL, FLOOR, FOUNDATION WALL, DOOR, AND WINDOW ASSEMBLIES

All existing residences being considered for financial assistance under the Section 502 and Section 504 housing programs should be evaluated: (1) to determine their existing thermal performance characteristics; (2) to compare their existing thermal performance characteristics against the target goals of the prescriptive standards chart provided in Rural Development Instruction 1924-A, Exhibit D, IV.B. (see the chart above); and (3) to determine whether it would be cost effective to upgrade their existing thermal performance characteristics if they do not measure up to the Exhibit D requirements.

Exhibit D generally draws the line on cost effectiveness based on whether or not an existing insulated space is currently "easily" accessible for insulation upgrading or would be accessible if exposed during otherwise intended rehabilitative construction. It may be cost effective to consider upgrading certain existing insulated areas that are not "easily" accessible, however, from a long-term energy bill payback perspective, if critical assemblies are severely under-insulated (i.e. no indication of insulation material present in some exterior walls). It is possible that augmentive insulation material could be pumped into or otherwise placed in such assemblies to be followed up by cosmetic repairs.

Please also note that adding insulation materials to some existing residences may stress already weak structural components (i.e. ceilings) and this should also be pondered when determining cost effectiveness, as such structural components may then need to be strengthened to support additional loading.

Following is a discussion of methodologies for evaluating selected construction components for their thermal performance characteristics against the Exhibit D criteria:

CEILING AREAS

(1) Inspect ceiling areas to determine the existing insulation material types and overall thicknesses.
(2) Determine the insulation material R values based on the "Thermal Resistance Properties…." chart provided below.
(3) Compare the observed R values for the insulation materials inspected against the minimum R value required in the "Ceiling" column of the RD Instruction 1924-A, Exhibit D, IV.B. table provided above, for the HDD zone for the location of the residence.
(4) Determine if the ceiling insulation materials could be cost effectively upgraded (i.e. by blowing in more loose fill insulation material) if they are significantly under the minimum standard recommendation provided in the RD Instruction 1924-A, Exhibit D, IV.B. table provided above.
(5) Consider the structural loading impacts of upgrading the insulation materials.

WALLS

(1) Inspect wall areas or otherwise determine the existing insulation material types and overall thicknesses.
(2) Determine the insulation material R values based on the "Thermal Resistance Properties…." chart provided below.
(3) Compare the observed R values for the insulation materials inspected or otherwise determined against the minimum R value required in the "Walls" column of the RD Instruction 1924-A, Exhibit D, IV.B. table provided above, for the HDD zone for the location of the residence.
(4) Determine if the wall insulation materials could be cost effectively upgraded (normally not) if they are significantly under the minimum standard recommendation provided in the RD Instruction 1924-A, Exhibit D, IV.B. table provided above.
(5) Consider the structural loading impacts of upgrading the insulation materials.

FLOOR AND RIM JOIST AREAS

(1) Inspect floor and rim joist areas to determine the existing insulation material types and overall thicknesses.
(2) Determine the insulation material R values based on the "Thermal Resistance Properties…." chart provided below.
(3) Compare the observed R values for the insulation materials inspected or otherwise determined against the minimum R value required in the "Floors/rim joists" column of the RD Instruction 1924-A, Exhibit D, IV.B. table provided above, for the HDD zone for the location of the residence.
(4) Determine if the floor and rim joist insulation materials could be cost effectively upgraded (i.e. by installing additional batt insulation) if they are significantly under the minimum standard recommendation provided in the RD Instruction 1924-A, Exhibit D, IV.B. table provided above.
(5) Consider the structural loading impacts of upgrading the insulation materials.

FOUNDATION WALLS

(1) Inspect foundation walls to determine the existing insulation material types and overall thicknesses.
(2) Determine the insulation material R values based on the "Thermal Resistance Properties…." chart provided below.
(3) Compare the observed R values for the insulation materials inspected or otherwise determined against the minimum R value required in the "Foundation walls" column of the RD Instruction 1924-A, Exhibit D, IV.B. table provided above, for the HDD zone for the location of the residence.
(4) Determine if the foundation wall insulation materials could be cost effectively upgraded (may be influenced by accessibility concerns) if they are significantly under the minimum standard recommendation provided in the RD Instruction 1924-A, Exhibit D, IV.B. table provided above.

WINDOWS

(1) Inspect windows to determine the existing types of glass.
(2) Determine the U values of the existing glass types based on the values provided in the "Low-emissivity coating", "Max. U = 0.47 window", and "Max. U = 0.69 window" discussions provided under "DEFINITIONS", above.
(3) Compare the observed U values for the existing window glass types against the maximum U value required in the "Windows" column of the RD Instruction 1924-A, Exhibit D, IV.B. table provided above, for the HDD zone for the location of the residence.
(4) Determine if the windows could be cost effectively replaced based on their type and suitability for easy replacement if they are out of compliance with the RD Instruction 1924-A, Exhibit D, IV.B. standard. (Partial replacement might also be considered if some would be easily upgradable.)

DOORS

(1) Inspect exterior doors to determine the existing types.
(2) Determine the acceptability of the existing types based on the acceptable types shown in the "Doors" column of the RD Instruction 1924-A, Exhibit D, IV.B. table provided above, for the HDD zone for the location of the residence..
(3) Replace the exterior doors if they are out of compliance with the RD Instruction 1924-A, Exhibit D, IV.B. standard.

Thermal Resistance Properties of Various Building Insulation Materials

(Building insulation material R-values shown below are extracts from the 1997 ASHRAE *"Handbook of Fundamentals"*, Chapter 22.)

BUILDING INSULATION MATERIAL	PER INCH THICKNESS	PER THICKNESS LISTED
Batt or blanket: rock, slag, or glass:		
3.5 inch (standard)		11
3.5 inch (high-R)		13
5.5 inch (standard)		19
5.5 inch (high R)		21
7 inch		22
9 inch		30
12 inch		38
Board or slab:		
Glass fiber, organically bonded	4.00	
Expanded polystyrene, extruded	4.00	
Expanded polystyrene, beads	3.57	
Polyisocyanurate	7.20	
Mineral fiber with resin binder	3.45	
Blown loose fill:		
Cellulose	3.13	
Expanded perlite	2.70	
Mineral fiber (rock, slag, glass):		
5 inch		11
8.75 inch		19
10 inch		22
13.75 inch		30
17.25 inch		38
Exfoliated vermiculite	2.27	
Sawdust	2.22	
Wood fiber	3.33	
Spray applied:		
Polyurethane foam	6.00	
Cellulose fiber	3.45	11
Glass fiber	3.85	19

All requirements of this ATG should be fully explained to applicants, contractors, and lenders, as appropriate, prior to obligating funds. Should you have any further questions on this subject, please contact the State Architect.

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